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High Temperature Deformation
and Fracture Behavior of Metals
under High Strain Rate Conditions

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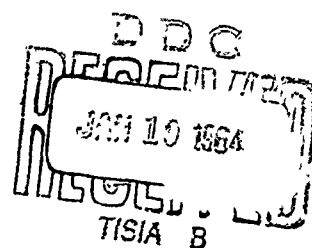
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Medford, Massachusetts

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I INTRODUCTION

A program had been initiated to evaluate the high strain rate deformation behavior of Udimet 700, beryllium and tungsten over a wide range of temperatures. The aim of the program is to develop an inexpensive, simple means for determining hot working parameters of hard-to-fabricate materials.

II EXPERIMENTAL TECHNIQUES

High strain rate tests were performed on a modified constant load creep machine. The equipment was described in a previous progress report.

III RESULTS AND DISCUSSION

a) Work on Udimet 700

A second set of specimens was cut from the outside of the ingot with the specimen axis tangential to the ingot surface and perpendicular to the ingot axis. The results differ in some respects from those obtained from axial specimens. A complete discussion of this portion of the work will follow in the next progress report. The discussion will include the results of the metallographic investigation.

b) Work on Beryllium

Table I summarizes the results obtained from a beryllium vacuum hot pressing. The specimens were cut parallel to the direction of pressing. Test temperatures covered the range between 700° and 1400° F. Table I includes the results of all these tests. The data points are plotted in Figures 1, 2, and 3.

The results very clearly indicate a strain rate sensitivity of the deformability of beryllium at all temperature investigated. At low temperatures - e.g., 700° F - the ductility in terms of total elongation decreases with increasing strain rate. A metallographic investigation shows that this decrease in deformability is due to the increasing tendency towards brittle fracture. At higher temperatures - 1100° F and higher - the ductility increases with increasing strain rate. Metallographic evidence indicates that intercrystalline cracking (due to creep deformation) is the reason for failure at lower strain rates.

In reviewing the deformability over the whole range of temperatures, at a given strain rate of 1 in/in/sec , it becomes apparent that there is a maximum of ductility around 1100° F . The range of high ductility is restricted by creep phenomena at higher temperatures and brittle fracture phenomena at lower temperatures (Figure 3).

As can be seen from Figure 2, the relationship between temperature and deformability is quite different with lower strain rate, as the ductility increases with decreasing rate of deformation (e.g., at a temperature of 700° F).

IV FUTURE WORK

Tests are in progress on Udimet 700 with a specimen axis tangential to the ingot surface.

The metallography of beryllium is perfected in order to show the various fracture mechanisms with photomicrographs.

A tungsten 3% molybdenum ingot has been prepared by Climax Molybdenum Company. This material will be used for the third part of this program.

Table 11 High Strain Rate Tests on Beryllium 2043 Vacuum Hot Pressing

<u>Code No.</u>	<u>Temperature (° F)</u>	<u>Stress (psi)</u>	<u>Life Seconds</u>	<u>Av. Deformation Rate in/in./sec.</u>	<u>% El.</u>	<u>% R.A.</u>
B2	700	40,000	0.008	3.100	2.5	3.9
B3	700	37,500	0.041	1.000	4.2	3.2
B5	700	35,000	2.384	0.026	6.3	6.7
B1	700	33,000	98.375	0.0016	16.0	21.7
B4	700	33,000	107.53	0.00132	14.2	19.1
B15	1000	37,500	0.038	2.374	9.1	11.3
B16	1000	33,000	0.198	0.697	13.8	16.4
B13	1000	30,000	3.571	0.038	13.7	23.6
B14	1000	27,500	5.577	0.022	12.1	23.6
B10	1100	32,500	0.060	2.411	14.4	21.1
B6	1100	28,000	0.478	0.276	13.2	19.0
B11	1100	22,500	14.886	0.004	7.2	12.5
B19	1200	28,000	0.100	1.260	12.6	19.7
B18	1200	25,000	0.246	0.496	12.2	19.9
B17	1200	20,000	6.878	0.008	5.4	12.9
B9	1300	22,500	0.119	1.067	12.7	13.9
B7	1300	20,000	0.232	0.392	9.1	13.6
B8	1300	17,500	0.568	0.114	6.5	7.9
B21	1400	20,000	0.062	1.000	6.2	14.3
B20	1400	15,000	0.203	0.354	7.2	5.8
B22	1400	10,000	0.881	0.029	2.6	3.9

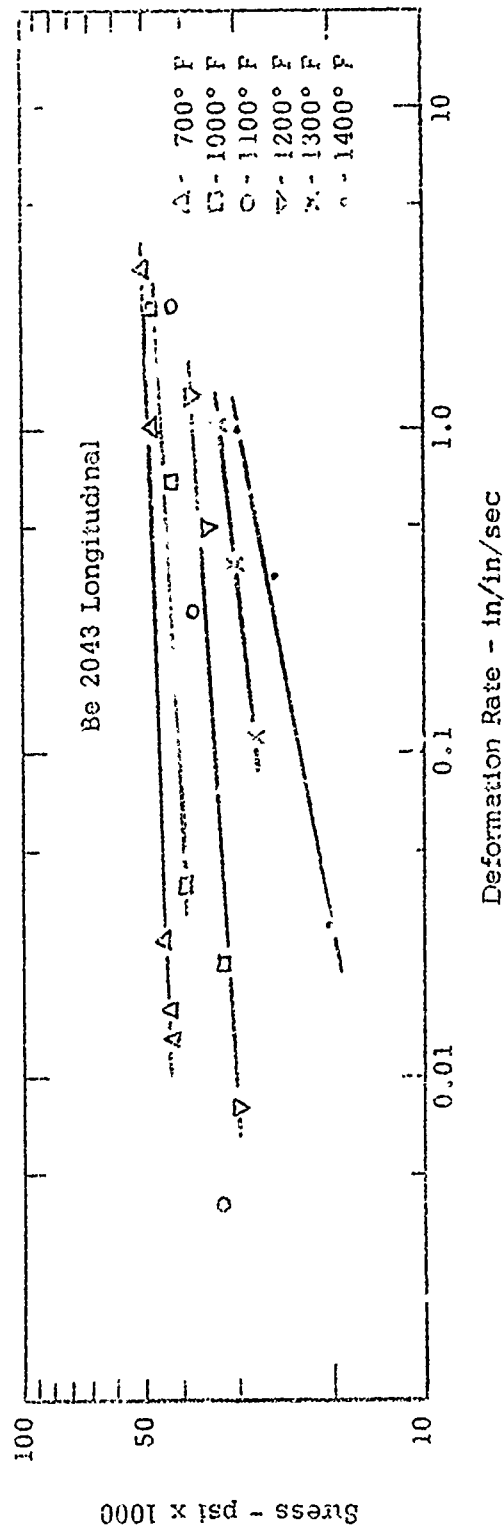


Figure 1: Stress as a function of deformation rate.

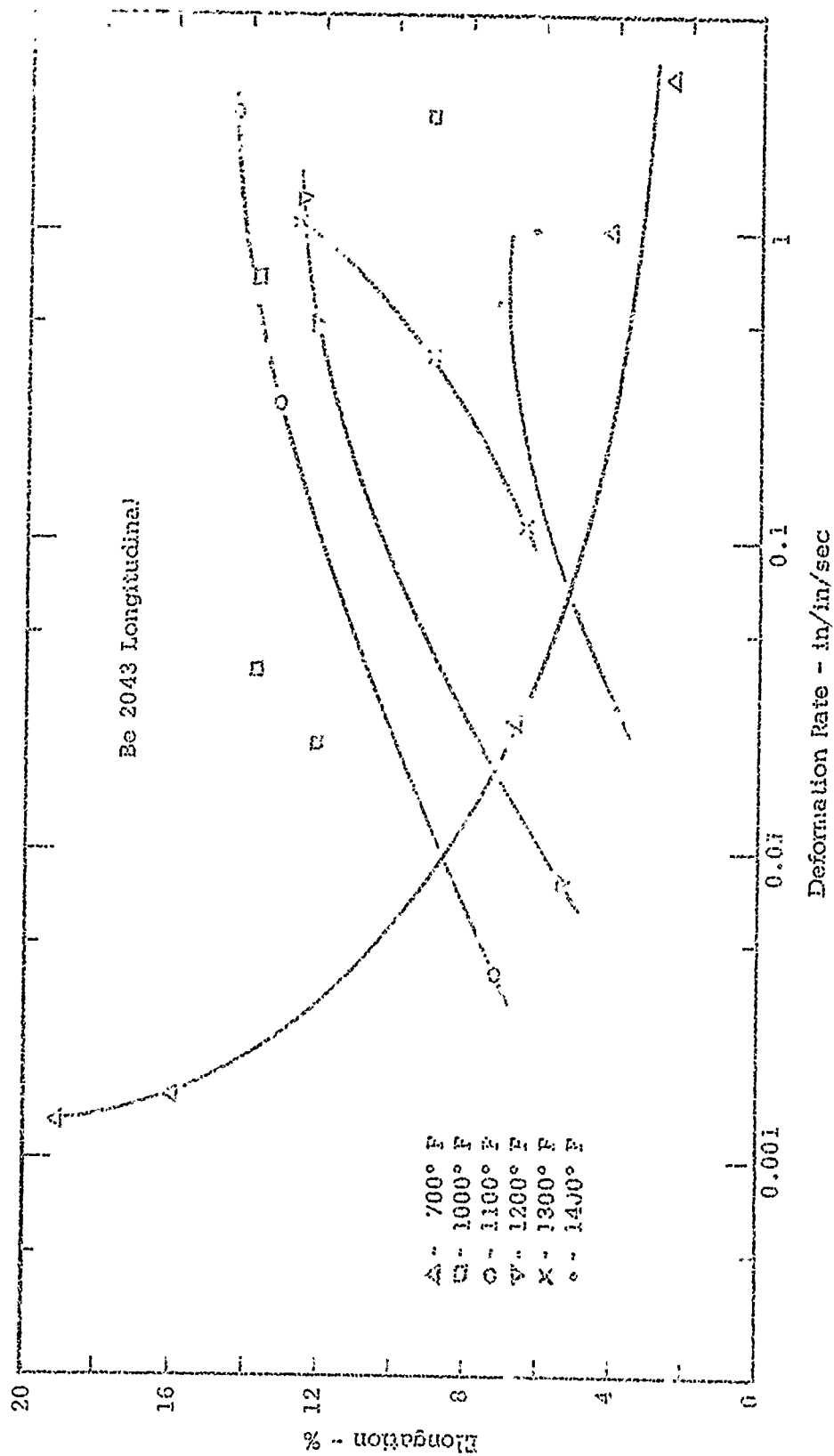


Figure 2: Elongation as a function of deformation rate.

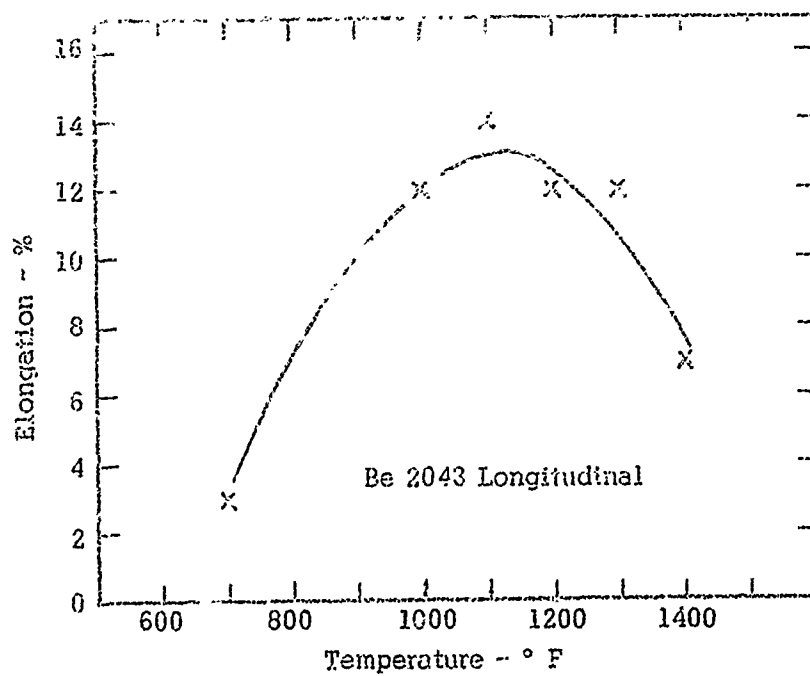


Figure 3: Total elongation as a function of test temperature (strain rate 1 in/in/sec.)